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Response of Aspen Suckering to Pre-harvest Stem Treatments: A Literature Review

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Response of Aspen Suckering to Pre-harvest Stem Treatments: A Literature Review

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EXECUTIVE SUMMARY

The purpose of this literature review is to provide background information on the suitability of pre-harvest aspen control as a silvicultural treatment for the southern interior of British Columbia. It has been requested by a joint committee of Okanagan Forest Districts, Okanagan licensees, and the Earthcare Society.

Aspen is not considered merchantable in the southern interior, but is regarded as a competitor to conifers on productive forest land. This competition can restrict the free growth of conifers, thus requiring some form of brushing treatment. Pre-harvest control provides a management solution before aspen becomes a competitive threat.

This study assessed three main treatment methods for their effectiveness in controlling aspen and for the various risks and impacts associated with their use. The methods were: stem-injection of herbicide; application of ground active herbicide; and girdling. From the available information it appears that all three methods have the potential for effective pre-harvest control of aspen. Although other studies have shown that suckering is reduced by such treatments, no work has yet determined what interval is needed between treatment and canopy removal to provide adequate control.

Operational experience indicates that a period of 2-10 years between treatment and harvest is required for effective control. However, the available information gathered on aspen physiology and control methods suggests that control is possible in less time. Study results show that suckers formed from roots of treated stems are not as vigorous as suckers from untreated stems, and that they suffer greater mortality for up to 10 years after treatment. This type of information can only be obtained from long-term studies. It is therefore suggested that any experimentation on pre-harvest control have follow-up assessments 5 and 10 years after canopy removal.

Questionnaire respondents perceived risk or impact of the treatments to be highest with ground active herbicide for all categories examined except worker safety. Actual risks or impacts depend on site-specific conditions.

Although available information suggests that girdling is economically and environmentally the most desirable of the treatments, the most effective timing between treatment and harvest is unknown and may be longer for girdling than for chemical treatments. This could restrict its operational use. Experimentation is needed to assess the time required for each type of treatment to provide effective control.

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1 INTRODUCTION

Aspen *(Populus tremuloides* Michx.) is a common component of many stands in the southern interior of British Columbia. It is not considered merchantable in this area and is often regarded as a competitor to conifers on productive forest land.

1.1 Purpose

The purpose of this literature review is to provide background information on the suitability of pre-harvest aspen control as a silvicultural treatment for the southern interior of British Columbia. It has been requested by a joint committee of Okanagan Forest Districts, Okanagan licensees, and the Earthcare Society.[1]

1.2 Background

Part of the B.C. Ministry of Forests' mandate is to assure that regeneration becomes free-growing after disturbance. Aspen, when found as a component in conifer stands, characteristically reestablishes sites rapidly after harvesting. This may result in dense aspen which competes with conifer regeneration, restricting their free growth, and requiring some form of brushing treatment.

Pre-harvest control is a management option that can reduce the competitive threat from aspen. It can be relatively inexpensive compared to post-harvest treatments, and it can often check potential problems, such as reduced growth or increased mortality of the crop species.

2 ASPEN LIFE HISTORY

Controlling aspen successfully requires a knowledge of its reproductive strategies and physiology. The following section is a brief description of aspen and its various strategies for regeneration.

2.1 Sexual Reproduction

Aspen grows into a medium-sized deciduous tree up to 25 m in height (Brayshaw 1976). Aspen are predominantly dioecious, where male and female flowers are borne on separate plants. Aspen begins to flower at approximately 10 years of age, producing seed crops annually, with good crops expected every 2 years. In southern Canada they flower in early April.

According to Maini (1972), an 11 m tall, 23-year-old aspen in southern Ontario produced an estimated 1.6 million seeds in an average year. Despite such prodigious seed quantities, however, establishment of aspen from seed under natural conditions is rare for the following reasons:

- short seed viability (2-3 weeks);
- the presence of a water-soluble germination-and-growth inhibitor in seed hair;
- unfavorable moisture conditions during germination; aspen requires a moist seedbed (this is considered the greatest limiting factor);
- mortality of germinants due to high surface temperature, especially on sites blackened by fire;
- the susceptibility of germinants to fungal attack;

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[1] See Appendix 5 for a list of selected annotated references.

- adverse influence of diurnal temperature fluctuations on initial seedling growth;
- unfavorable chemical nature of some substrates on which the seeds are likely to fall (Maini 1972).

2.2 Vegetative Regeneration

Usually, aspen regenerates vegetatively, rather than by seed. It forms suckers, which are adventitious shoots on roots (Farmer 1962; Barnes 1966; Maini 1972; Steneker 1976; Schier and Campbell 1976; Perala 1984). When mature aspen stands are killed, initial stocking can be as high as 200 000 suckers per hectare (Steneker 1976). Perala (1984) found that initial stocking rates of 128 000 stems per hectare were reduced to 7300 stems per hectare within 7 years, due to self-thinning.

Suckers are produced from a shallow lateral root system (Steneker 1976; Schier 1981). Most are borne on roots that range from 0.5 to 5 cm in thickness, and are located in the upper 2.5-10 cm of the soil profile. Graham *et al.* (1963, cited in Perala 1972) report that suckers can originate up to 24 m from the original stump. Sprouts from the stump or root collar are uncommon, but may occur (Maini 1972).

Aspen grows best on moist clay-loams and on well-drained but moist sandy-loams, with adequate groundwater reserves within 2 m (Steneker 1976).

2.3 Physiology of Suckering

Suckering is thought to be driven by the balance of auxins and cytokinins, and influenced by temperature. Farmer (1962) found that aspen suckering was inhibited by auxins produced in the apical meristems. Auxins are formed in the swelling buds, growing shoots, and leaves, and are then transported via the phloem to the roots (Eliasson 1971, 1972).

Sucker establishment is likely initiated by cytokinins, which are hormones produced in the root tips (Williams 1972; Peterson 1975, cited by Schier 1978; Skene 1975). Because cytokinins move through the xylem, severing only the phloem does not affect cytokinin root concentrations. Fig. 1. A high ratio of cytokinins to auxins contributes to shoot initiation; low ratios inhibit it (Winton 1968; Wolter 1968). Fig. 2.

Suckering is stimulated by elevated soil temperatures. Steneker (1976) found soil temperatures of 20-30°C to be optimal. Shirley (1931, 1932) found suckering to be enhanced by light burning, suggesting that stimulation was due to increased heat absorption by the blackened surface. Maini and Horton (1966) found that suckering was stimulated significantly between 18 and 30°C and suppressed at 14 and 35°C.

The stimulation of sprouting at elevated temperatures appears to be caused by an increase in the effectiveness of cytokinins (Williams 1972, cited by Schier *et al.* 1985). As well, auxin degradation occurs at elevated soil temperatures, further increasing the cytokinin to auxin ratio (Schier 1976). This explains why sprouting may occur in conifer clearcuts where aspen has been left standing.

2.4 Stand Management and Suckering

Cutting aspen increases the ratio of cytokinins to auxins because the auxin flow to the roots is cut off from its apical source. Cytokinin levels also increase because they are restricted to the rooting area. At the same time, canopy removal allows for increased surface temperatures which enhance the effectiveness of cytokinins. The result is prolific sprouting.

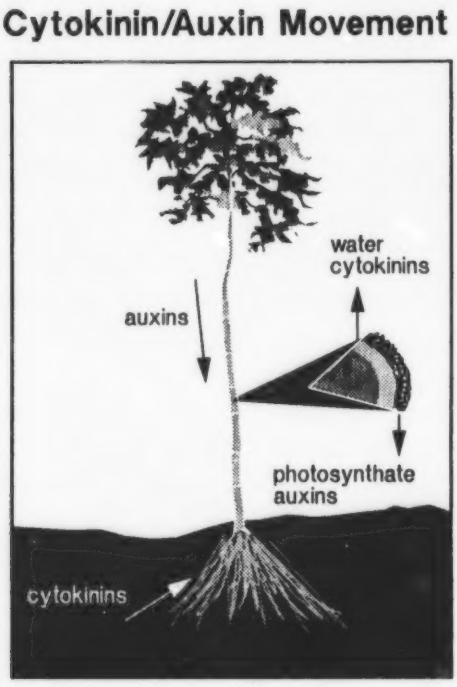

FIGURE 1. Cytokinin/Auxin movement in Aspen.

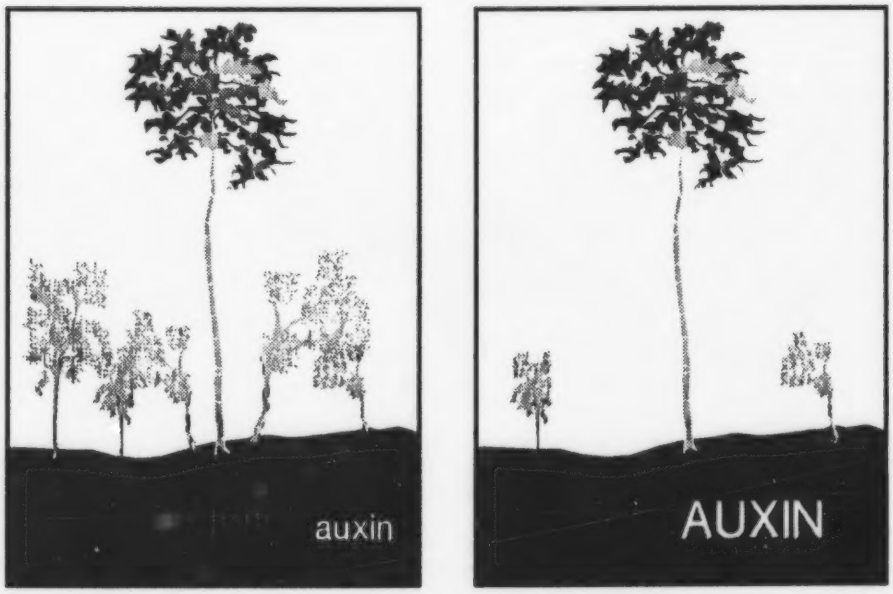

FIGURE 2. Cytokinin/Auxin ratio and its effect on suckering.

2.5 Clones

Regeneration, by sprouting from a root system, results in the formation of clones of genetically identical trees. Different clones can vary in genetic attributes, such as growth rates or ability to sucker (Perala 1972). Garrett and Zahner (1964) found a six-fold variation in suckering response to the same stimulus in six different clones of bigtooth aspen (*Populus grandidentata* Michx.). Maini and Horton (1966) found different clones of trembling aspen to have up to 20-fold variation in the number of suckers after clearcutting, depending on temperature regime. According to Schier and Johnston (1971), significant differences in total nonstructural carbohydrates occurred in six clones, in each of three different areas in Utah. They suggested that clonal differences may result in variable initial sucker growth. This variation has major implications in experimental design, as clonal differences could obscure the significance of treatment effects.

In southern British Columbia, clone sizes are small, not forming extensive stands.

2.6 Season of Cutting

In northern Minnesota, the season of cutting was found to affect aspen sprouting (Zehngraff 1946). Spring cutting of aspen stands delayed sucker production until midsummer. Many were not hardened off sufficiently by fall and were winter-killed. Summer logging resulted in delays of suckering up to midsummer of the next year, but winter cutting created abundant suckers the next summer.

2.7 Shade Intolerance

Aspen is a shade-intolerant tree which requires full sunlight for growth (Lutz 1955, cited by Haeussler and Coates 1986; Krajina *et al.* 1982).

Farmer (1963) found that laboratory-grown aspen responded both to light and temperature: at light levels between 5 and 17% of full sunlight, growth was inhibited with high temperature.

3 PRE-HARVEST ASPEN CONTROL TREATMENTS

This section describes what is known about pre-harvest aspen control from the published and unpublished literature. Responses from a questionnaire[2] circulated to government and industry representatives who have used pre-harvest control, or are familiar with the treatments, were used to provide local information and opinions on the subject.

The treatments are discussed under the following headings (adapted from Haeussler and Coates 1986):

Treatment group Two main groups of treatment, chemical and manual, are addressed in this report. Biological control techniques are presently experimental and are not dealt with here.

Chemical treatments include all methods that use herbicides. Herbicides are classed as pesticides, and thus their use must conform to federal and provincial laws and regulations. Manual treatments include girdling and cutting. There are no regulations governing their silvicultural use other than those set out by the Workers' Compensation Board.

Treatment method Within each treatment group, a number of methods are available for aspen control. Methods which are similar in action but use a different tool to accomplish the same task, are combined for the following analyses. Differences in effect or safety are addressed. Different chemicals for the same application method are assessed independently.

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2 A copy of the questionnaire is located in Appendix 1.

Treatment effects Each treatment method is assessed according to the following criteria:

1. timing between treatment and harvest
2. seasonal timing for optimal control
3. sprouting potential after treatment
4. ground and stream water quality
5. physical, chemical, and biological characteristics of the soil
6. effects on the post harvest conifer crop
7. effects on wildlife and wildlife habitat
8. worker safety

Questionnaire respondents were asked to rank the probability of risk or impact relating to the treatment for criteria (4) through (8). The responses supplement the published information on the subject, and provide a rough ranking of potential concerns by treatment type.

A list of locations is provided for each treatment type. The local contact is noted and provided in Appendix 2.

3.1 Chemical Treatments

3.1.1 Tree injection - glyphosate, 2,4-D

Hack and squirt The term "hack and squirt" is both the name and description for the process. A notch or "hack" is made into the side of a stem with a downward stroke of an axe, hatchet, brush-hook, or similar tool. It is followed by a squirt of herbicide solution applied to the notch. The purpose is to kill the plant by injecting a measured amount of concentrated chemical within the inner bark or cambium of the target stem.

To regulate dosage, the distance between injections is adjusted or the concentration of the herbicide is varied. The Ministry of Forests requires a minimum of two notches per stem, with the total number of notches depending on the chemical used and the stem diameter (B.C. Ministry of Forests 1987). Dosages that have been used to date for pre-harvest aspen control are presented in Table 1.[3]

Full concentration of either glyphosate (Roundup®[4]) or 2,4-D amine applied in August at 1 mL/5 cm dbh and 1 mL/3 cm dbh, respectively, resulted in total aspen top-kill.[5] This agrees with Newton who suggested full concentration of glyphosate be applied at 1 mL/5 cm dbh in late summer to get total control.[6] One notch every 15 cm around the circumference is required to achieve this dosage level.

Dosages and timing should have similar efficacy for other injection methods.

Other injection methods Hypo-hatchet is a form of hack and squirt where the herbicide is transmitted through a tube into the "hack" through the head of the hatchet. This is done in a single motion. It is more productive per man-day than the traditional hack and squirt technique, when the device is working properly (Newton and Knight 1981). Downtime is reduced when operators are

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3 It should be noted that most of the results presented in Table 1 as "measures of success" are not based on experimentally designed plots that have proper replication and controls. Instead, they are visual estimates made on operational treatments. These estimates vary considerably by observer, but offer a first approximation of treatment effectiveness and should be viewed as such. Since individual observers used different parameters to measure success, such as death of the injected stem versus reduction of trees sprouting, comparisons of success are difficult.

4 The product Roundup® by Monsanto has since been renamed Vision® for forestry use.

5 Ackerman, G. B.C. Ministry of Forests, Silviculture Branch, Victoria, B.C. Questionnaire respondent.

6 Newton, M. pers. comm., March 1988.

TABLE 1. Rate and success of operational injection methods

Agency	Chemical	Rate	Date	%Success			Measure of success
				yr 1	yr 2	yr 3	
BCFP	Roundup®	1mL[50% H_2O] /10 cm dbh	84	30	65	85	death of injected stem
BCFP	Roundup®	as above	85	35	70		as above
BCFP	Roundup®	as above	86	35			as above
FINLAY	Roundup®	1 mL [50%] /5 cm dbh	Sep 85	——	Failure	——	suckering (logged same winter as treated)
FINLAY	Roundup®	as above	Nov 86	95			% defoliated
FINLAY	Roundup®	as above	Nov 84			75	% defoliated
FINLAY	Roundup®	1 mL [33%] /5 cm dbh	Nov 85			85	% defoliated
FINLAY	Roundup®	1 mL [25%] /5 cm dbh	Nov 85			80	% defoliated
FINLAY	Roundup® Dillistone Caps	0.2 g a.i./cap per 3 cm dbh	Feb 85	90			% defoliated
BCFS[a]	Roundup®	1 mL/5 cm dbh	Aug 85	100			% defoliated 0% resprouting
BCFS[a]	2,4-D	1 mL/3 cm dbh	Aug 85	100			% defoliated 0% resprouting
CANFOR	Roundup®	2 mL [50%] /10 cm dbh	Aug 86	73-95			death of treated stems
LAKELAND	Roundup®	1 mL [100%] /2.5 cm dbh	Jul-Sep 85-87	Nil			reduction of trees sprouting
LAKELAND	2,4-D	1 mL [100%] /3 cm dbh	Jul-Aug 82-84	0			reduction of trees sprouting
CROWN	Roundup®	2.5 mL [100%] /5 cm dbh	May-Jul 86	90			visual estimate of stems dead or dying
BCFS[b]	Roundup®	2 mL [100%] /5 cm dbh	Sep 84	100			0-100% ranking of defoliation
BCFS[b]	Roundup®	2 mL [50%] /5 cm dbh	Sep 84	100			0-100% ranking of defoliation
BCFS[b]	Roundup®	2 mL [25%] /5 cm dbh	Sep 84	98			0-100% ranking of defoliation
BCFS[b]	Roundup®	2 mL [12.5%] /5 cm dbh	Sep 84	98			0-100% ranking of defoliation
BCFS[c]	Roundup®	2 mL [50%] /3 cm dbh	Aug 84	100			top-kill estimate[d]
BCFS[c]	Roundup®	2 mL [50%] /3 cm dbh	Aug 85	100			top-kill estimate

Source: Questionnaire responses
BCFP: Fletcher Challenge Canada (formerly British Columbia Forest Products)
BCFS: British Columbia Forest Service

a sx 84704-Q

b von Hahn, C. 1985.

c Vanderhoof Forest District, operational data.

d This site was logged 1 year after treatment, and aspen suckering was evident on the block after harvesting. Density was not quantified.

trained in the complexities of the mechanism. It is suited for clumps of trees and steep terrain due to the one-handed operation. Cuts located high on the tree, however, increase the risk of face spattering with concentrated herbicide (Newton and Knight 1981).

Reported problems include clogging of the delivery channel, with wood splinters creating herbicide flow stoppages. In some cases, herbicide has remained on the blade from the previous cut and splashed on the worker when he has made the next notch. Modifications, such as enlarging the delivery channel diameter and reducing excess metal on the head, have given some workers considerable application success (B.C. Ministry of Forests 1987).

The Ministry of Forests' lance injector has a 1.8-m stainless steel tube with a cutting head and injector at the basal end. The tube is filled with liquid herbicide. The lance allows stem treatment without removal of obstructing brush. Weight and cost appear to have restricted its use (Henigman and Beardsley 1985).

This tool, and other non-encapsulated injection techniques, require workers to handle concentrated herbicide when refilling applicators, and this increases the risk of worker exposure to the chemical.

Encapsulated Injection Encapsulated injection involves methods that use a capsule of herbicide which is directly injected into the tree. The Dillistone Wee-Do Injector® uses 0.22-inch cartridges filled with herbicide and a solidifying agent. To drive the cartridges into the tree stem, the head of the lance is pressed against the stem. Dose depends on the number of cartridges used, and the number is based on tree diameter.

B.C. Hydro developed a glyphosate and gel capsule that screws into the stem. It is now being marketed as Gel Cap® by Pace Chemicals. The system uses a cordless screwdriver with an automatic feeding mechanism for the capsules.

With either encapsulated system there is little chance of environmental contamination or worker contact with concentrated herbicide, and application can be performed in the rain. However, there are some drawbacks. Equipment may jam, causing delays. As well, logistical problems may result if enough cartridges or caps are not carried to treat all the required stems. When stem density is high, or tree diameter is large, more capsules are needed to ensure mortality. The B.C. Hydro rule of thumb is one cap with 1 mL of glyphosate for every 5 cm dbh, spaced equally around the circumference of the stem[7]. In dense stands, or in areas of large stems, this is time consuming. Gray[8] found the Gel Cap® screws too short and the plastic cutting edges too weak to allow older thick-barked aspen stems to be treated properly.

Finlay Forest Industries Ltd. of Mackenzie has tried both forms of encapsulated injection on a trial basis. They have no efficacy information on the Gel Cap® yet, but found that the Wee-Do caps provided *90%* defoliation after 1 year. Because of the nature of their trials, the costs were high, approximately $2.90 per stem for the Wee-Do capsule and $2.33 per stem for the Gel Cap®. Costs of hack and squirt generally vary from $0.75 to $3.00 per stem, depending on contractor availability, access, terrain conditions, stem density, stem diameter and other complicating factors. An average cost is $1.40 per stem.[9]

3.1.1.1 Treatment effects

Aspen mortality Aspen mortality is influenced by treatment timing, dosages, clonal resistance, and care in application. Information from the questionnaire respondents about aspen mortality by injection treatments is summarized in Table 1.

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7 Roddick, R. Vegetation Management Officer, B.C. Hydro, pers. comm., October 1986.
8 Gray, R. Stand Tending Coordinator, B.C. Ministry of Forests, Kamloops, pers. comm. of preliminary trials with Gel Cap®, April 1988.
9 from questionnaire responses.

If treated with the appropriate concentration (1 mL/5 cm dbh [100%]), at the right time (late summer), glyphosate should kill the aspen outright in one season.[10] In a herbicide rate trial, von Hahn found that 2 mL/5 cm dbh of Roundup® at various concentrations was effective at causing aspen defoliation the following growing season. Roundup® concentrations of 50 and 100% provided 100% defoliation, while concentrations of 12.5 and 50% resulted in 96% defoliation on one site and 100% on a second.[11] The aspen treated with 100% solution exhibited some streaks of cambial necrosis 15-20 cm below the root collar.

Root death or weakening is essential to reduce suckering. Therefore, visual estimates of above-ground death are only a tentative indication of the ensuing success of the treatment.

The information in Table 1 shows that defoliation is possible with pre-harvest treatments. Effectiveness ranged from 30 to 100% defoliation after one growing season. The two B.C. Forest Service trials appeared to have greater success than most of the operational applications, possibly because of the greater quality control in the experimental setting.

Although defoliation and, to a lesser extent, reduced suckering were used to assess treatment success, the true test is the extent of post-harvest suckering, sprout vigor, and longevity. This information, along with crop response, is not available either operationally or experimentally.

Timing Interval Questionnaire responses indicate a divergence of opinion on the time required between control and harvesting: See Table 2.

TABLE 2. Timing needed between treatment and harvest for effective control: operational opinions

Contact	Time between treatment & harvesting
B. Zak B.C. Forest Products Mackenzie	3 years minimum
D. Perdue Finlay Forest Industries Mackenzie	2 - 3 years
Gord Acherman B.C. Ministry of Forests Victoria	1 year (based on sx results)
Don Roy Canfor Prince George	2 years minimum
John Casteel Lakeland Mills Prince George	7 - 9 years

Further information is required before an optimal interval between treatment and harvesting can be determined. Trials assessing suckering more than one growing season after harvest should be established. Until then, current information indicates that treatment 3 years before harvesting should be effective.

10 Newton, M. pers. comm., March 1988.

11 von Hahn, C. 1985. Control of aspen suckering by pre-harvest hack and squirt of Roundup®. Professional report for the ABCPF. Unpubl. manuscript. 44 p.

Seasonal timing Timing of application affects the distribution of the chemical because of differences in phloem movement. The greater phloem transport to the roots after the active growing season makes it potentially the most effective treatment time.

Glyphosate is a systemic herbicide which is phloem mobile. In woody stems, some of the herbicide accumulates in stem or root tissue housing meristimatic activity (Lund Hoie 1985). Intact molecules of glyphosate have also been found to exude from the roots of some treated plant species (Coupland 1985).

No set operational pattern emerged for timing of treatment. B.C. Forest Products and Finlay found no differences in fall and winter treatment effectiveness; and B.C. Forest Products indicated no variation found by month of application. The SX trials reported by the Ministry of Forests were treated in August and were considered successful. The trial reported by von Hahn had excellent defoliation success when treated in September. None of the treatment dates tried by Lakeland Mills, July through December, produced satisfactory results.

Differences in control found by the various respondents may have been due to different concentrations as well as timing.

Aspen sprouting Unless the roots have been killed, aspen regenerates by sprouting after canopy removal. One site treated by Finlay Forest Industries and logged in the same year had no reduction in sprouting. On the other hand, in a block treated with 2,4-D by hack and squirt, 1 year between treatment and logging, 90% reduction in sprouting occurred.[12]

Crombie (1965) found no sprouting from killed aspen stems frilled with the addition of 2,4,5-T, but according to Waldron (1961) there were generally no more suckers on sites treated by 2,4,5-T in basal frills or basal bark spray than on untreated sites. However, he was unable to directly attribute the controlled sprouting to the treatment, because of the site's heavy brush.

Ground and stream water quality If done correctly, injection methods have little chance of allowing herbicides to enter either the ground water or adjacent streams. Care must be taken when equipment is washed to ensure that herbicide does not enter any bodies of water. Rain directly after a treatment can result in some washoff of the chemical, reducing its effectiveness and potentially allowing small volumes to enter water courses or groundwater. However, volume of chemical used for this type of treatment is so low that any observable effects would be unlikely.

Soil characteristics Injection methods, by their nature, do not involve any direct contact between soil and chemical. Soil contact by the chemical could occur due to spills, washoff from the stem by rain, or movement of the chemical through plant roots. Exudation through the roots has not been tested in aspen.

Glyphosate has low phytotoxicity when applied to soils. It is generally considered soil immobile. Microbiological degradation is the main form of decomposition in the soil. The half-life is normally less than 60 days (Weed Science Society of America 1983). The rate depends on the soil microfloral population and temperature. There are no known adverse affects on soil microflora. The main soil metabolite is aminomethyl phosphonic acid (B.C. Ministry of Forests 1987).

Mobility of 2,4-D in soil is related to pH, water flux, organic, and clay content. It bonds extensively to organic matter, and undergoes some photodecomposition. Volatilization depends on formulation and is lowest in oil-soluble amines. The microbial breakdown rate depends on temperature, moisture, and soil organic matter content: warm, moist soils with high organic matter content have high breakdown rates. The half-life is 1-4 weeks in warm moist soils (B.C. Ministry of Forests 1987).

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12 Hodges, K.G. 1987. An evaluation of a pre-harvest deciduous seed tree control program. Professional report for the ABCPF. Unpubl. manuscript. 41 p.

Basham (1982) found the root rot fungus *Armillaria mellea* to be more common in root systems of aspen sprayed with 2,4-D than in those of unsprayed suckers. Many conifers on the treated site were infected as well. No evidence to date suggests that injection treatments result in increased rates of root rot in aspen or conifers. However, because of the importance of root rots, the effects of injection treatments on rot incidence should be validated.

Questionnaire results showed that most respondents (80%) perceived a low probability of risk or impact to the soil characteristics from tree injection treatments (Fig. 3)

Post-harvest conifer crops As stem injection is a selective treatment, there is virtually no chance of herbicide damage to post-harvest crop species from direct chemical exposure. Most questionnaire respondents (72%) assumed a low probability of risk or impact to the post-harvest crop (Fig. 4).

Wildlife and wildlife habitat The period of decay after the main stem dies is a concern for wildlife habitat. Keisker (1987), in south-central British Columbia, found that aspen stems with heart rot were used more frequently by cavity-nesting birds than healthy stems. As well, aspen was used for nesting more frequently than any other tree species in the area. In British Columbia, 85 wildlife species use snags for habitat.[13] Future deciduous control experiments should also examine impacts on snags for habitat potential.

All pre-harvest treatments, if effective, will kill the overstory aspen and reduce potential suckering. This influences the rate at which canopy closure is achieved and could produce indirect effects, such as reducing shelter for some species or changing understory forage and browse production (Harcombe 1984). However, unless the change limits critical habitat requirements for a particular species, the impact of such indirect effects should be minimal. Because some standing mature aspen are important habitat requirements for cavity dwellers, a policy whereby some areas are left untreated is a priority of wildlife managers.[14]

The reduction of aspen suckers over large areas may have negative effects on deer which use aspen as a main component of their diet (McCaffery *et al.* 1974, cited in DeByle 1976). This may not be a serious problem in southern British Columbia because of the scattered nature of the aspen.

Sullivan (1988a, in press) found small mammal population densities were not adversely affected by foliar application of glyphosate, nor were their growth and reproductive rates (Sullivan 1988b, in press).

Direct effects Due to the small amounts of chemical used in pre-harvest aspen treatments, direct effects should be negligible. There are, however, several viewpoints on the use of herbicides.

Public skepticism about the effects of chemical treatments has arisen partly out of a distrust of the regulatory procedure. In one incident, at Industrial Biotest Laboratories in the United States, registration test results were fabricated for a number of compounds including glyphosate. Another reason for skepticism is that background data for registration has only recently become available. The Freedom of Information Act in the United States has been used successfully to obtain original study results from the EPA (Environmental Protection Agency). It is not yet possible to do the same in Canada, but the U.S. information is available to Canadians through the U.S. Freedom of Information Act, Washington, D.C.[15]

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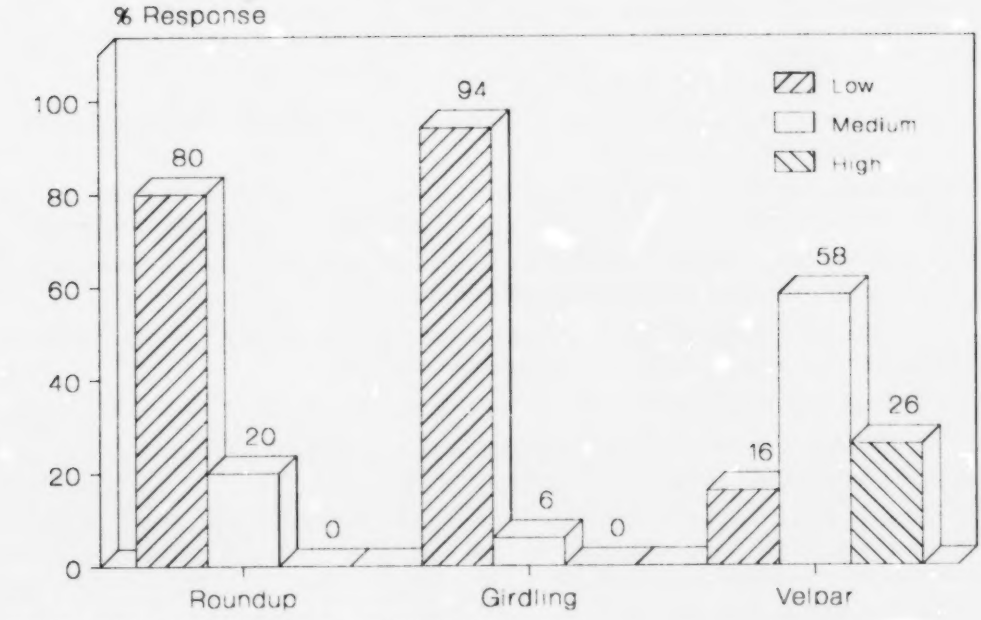
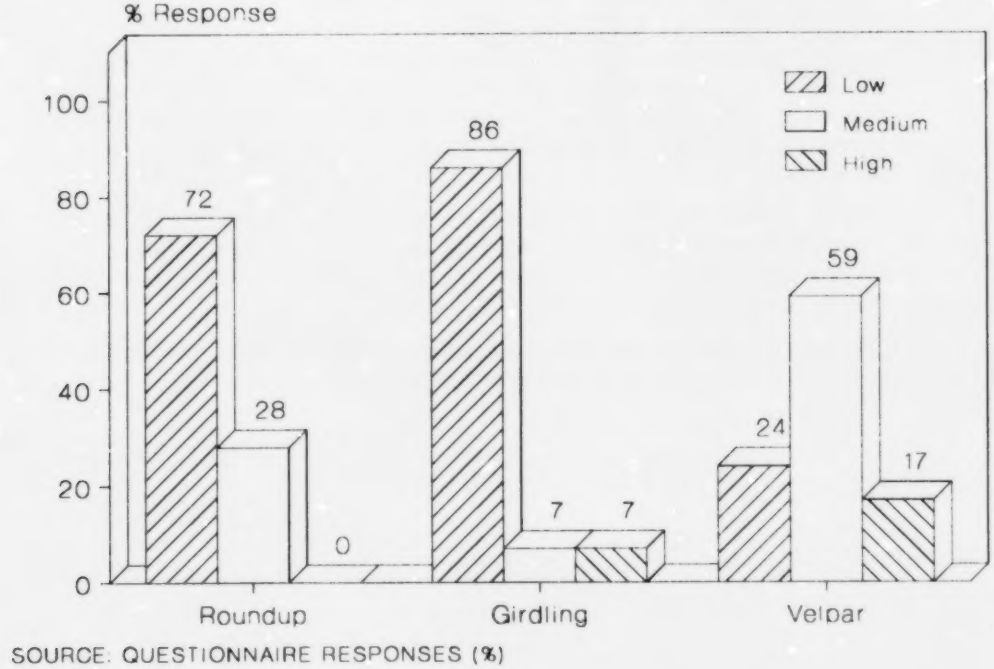
13 von Shuckman, S. February 1988. Presentation to the Integrated Vegetation Management Association of B.C.
14 Harcombe, A. Habitat Research Specialist, B.C. Ministry of Environment, Wildlife Branch, pers. comm., March 1988.
15 Taylor, L. Monsanto, pers. comm., November 1988.



SOURCE: QUESTIONNAIRE RESPONSES (%)

FIGURE 3. Herbicide use and risk to soil characteristics: Perception of respondents.



SOURCE: QUESTIONNAIRE RESPONSES (%)

FIGURE 4. Herbicide use and risk to the post-harvest crop: Perception of respondents.

Health and Welfare Canada stresses that the total formulation of Roundup® has now been totally retested[16]. Dr. Bowering, in an up-to-date study on the issue, concluded the following:

- Roundup®'s acute tocixology to mammals is extremely low.
- Based on test results in rabbits (see Appendix 4) Roundup® is considered a mild to moderate skin and eye irritant.
- Monsanto claims, and Health and Welfare Canada concurs, that there have been no confirmed reports to date of acute toxicity to humans resulting from exposure.
- There is no evidence that Roundup® is carcinogenic, mutagenic, or teratogenic to animals followed over several generations for several years.

The herbicide 2,4-D has also been used in treating aspen by stem injection. Toxic effects on wildlife have not been documented (Walstad and Dost 1984).

Toxicological information for glyphosate, 2,4-D, and hexazinone is provided in Appendix 4.

Questionnaire respondents felt that injection by glyphosate has the potential for a range of risks or impacts on wildlife and wildlife habitat, (Fig. 5).

Worker safety Workers using injection methods other than those where compounds are encapsulated could come in contact with full concentration of the herbicide. The potential consequences of exposure are as follows:

i glyphosate: symptoms of glyphosate exposure as reported by the U.S. EPA pesticide monitoring system were, for 34 cases: 15% had headaches, 24% had skin rash or itching, 29% had nausea or vomiting, 41% had eye irritation or inflammation, 15% had dizziness, 3% had sore throats (U.S. EPA 1980). Proper safety precautions can avoid such incidents. As with bee stings or allergies people have varying susceptibility to different stimuli. It is therefore important to limit exposure.

ii 2,4-D: recent studies in Sweden and one in Kansas show a potential correlation between repeated herbicide contact and an elevated risk of soft tissue sarcomas in humans (Hoar *et al.* 1986). Although this type of information has led some provincial governments to reconsider the status of 2,4-D, British Columbia has not acted to date.

Questionnaire respondents perceived a range of potential risks or impacts on worker safety (Fig. 6). Forty-eight per cent thought there was a low possibility of risk or impact, 33% a medium risk, and 19% a high risk. This divergence of opinion appears to rest on individual perception of chemical safety and the ability of workers to follow proper procedures.

The Workers' Compensation Board of British Columbia does not distinguish manual treatments of control from herbicide treatments in their rate structure.[17]

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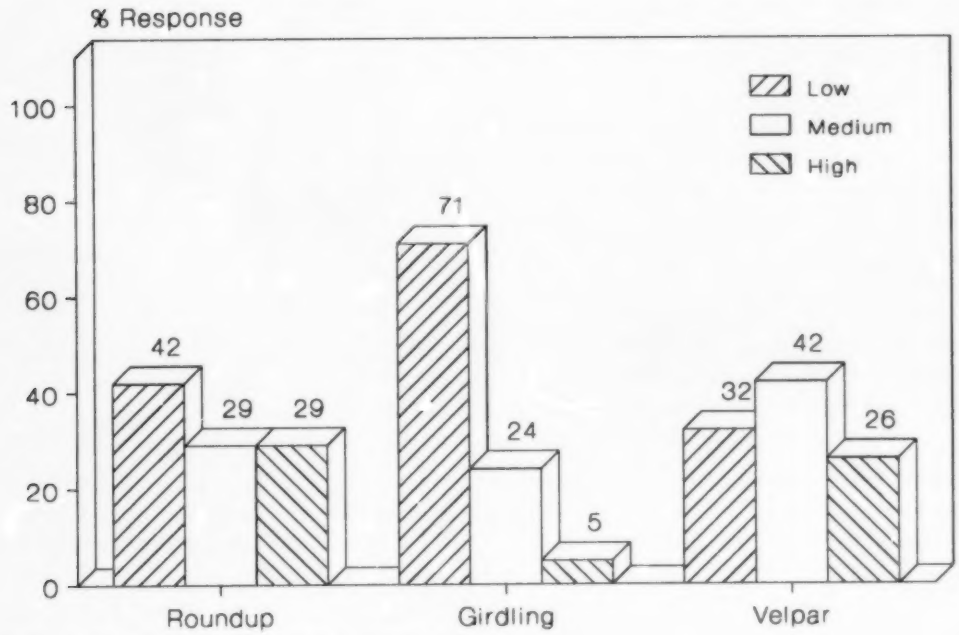
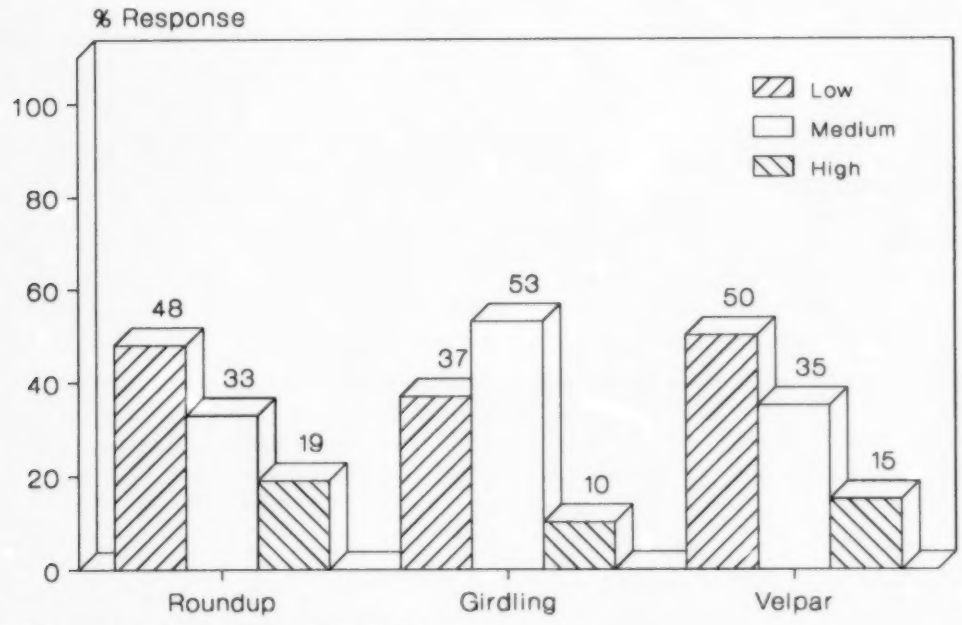
16 Bowering, D. 1987. Report to Kitimat District Council regarding medical consequences of herbicide spraying at the Golden Townhouse rental units. Dr. Bowering is the Community Physician/Medical Health Officer for the Terrace area, and is trained in epidemiology.

17 Matheson, G. Occupational Safety Officer, B.C. Worker's Compensation Board, pers. comm., November 1986.



SOURCE: QUESTIONNAIRE RESPONSES (%)

FIGURE 5. Herbicide use and risk to wildlife and wildlife habitat: Perception of respondents.



SOURCE: QUESTIONNAIRE RESPONSES (%)

FIGURE 6. Herbicide use and risk to worker safety: Perception of respondents.

3.1.1.2 Demonstrations of available treatment methods

The following table provides a list of locations where pre-harvest stem injection treatments have been used.

Agency	Herbicide	Location	Size (ha)	Year treated
BCFP	Roundup®	Mackenzie	295	1984
BCFP	Roundup®	Mackenzie	2669	1985
BCFP	Roundup®	Mackenzie	4049	1986
BCFP	Roundup®	Mackenzie	2241	1987
FINLAY	Roundup®	Mackenzie	171	Sep 85
FINLAY	Roundup® Wee-Do Caps	Mackenzie	8	Feb 85
FINLAY	Roundup® Hydro caps	Mackenzie	5	Nov 86
FINLAY	Roundup®	Mackenzie	423	Nov 86
FINLAY	Roundup®	Mackenzie	377	Sep 87
FINLAY	Roundup®	Mackenzie	14	Nov 84
FINLAY	Roundup®	Mackenzie	14	Nov 84
FINLAY	Roundup®	Mackenzie	11	Nov 84
BCFS	2,4-D Amine	Victoria	0.5	Aug 85
BCFS	Roundup®	Victoria	0.5	Aug 85
CANFOR	Roundup®	Prince George	2292	Aug 87
CANFOR	Roundup®	Prince George	1015	Aug 86
LAKELAND	Roundup®	Prince George	?	July-Sep 85-87
LAKELAND	2,4-D	Prince George	?	July-Aug 82-84
CROWN	Roundup®	Kelowna	507	May-July 86
CROWN	Roundup®	Kelowna	146	Dec 87
CROWN	Roundup® Carbopaste	Kelowna	219	Dec 87
BCFS	Roundup®	Vanderhoof	60	Aug 84
BCFS	Roundup®	Vanderhoof	200	Aug 85

BCFP: Fletcher Challenge Canada (formerly British Columbia Forest Products)
BCFS: British Columbia Forest Service
Contacts for the above operational work are provided in Appendix 2. A few of the sites have been logged since treatment, but no post-harvest suckering studies are completed at this time.

3.1.1.3 Operational Guidelines

In general, preliminary operational results, as outlined by questionnaire respondents, indicate that a 3-year period between treatment and harvesting is adequate for effective control. Lakeland Mills of Prince George suggested a much longer period was needed. Results from two SX trials suggested that a 1-year delay may be adequate for effective control. The use of 100% glyphosate at 1 mL/5 cm dbh or 100% 2,4-D amine at 1 mL/3 cm dbh gave 100% top kill after 1 year when applied in August. A separate study found concentrations as low as 12.5% glyphosate at 2 mL/5 cm dbh provided nearly complete defoliation the next growing season after September application.

3.1.2 Ground-active hexazinone

The use of ground-active herbicides such as hexazinone (DuPont tradename is Velpar®) is an alternative to stem injection. The liquid herbicide is injected into the forest floor either in a grid pattern or near target stems; or solid pellets are spread onto the soil by hand or from the air. The chemical enters the plants through the roots, killing some species (Sutton 1986).

Hexazinone is thought to be translocated primarily through the xylem. This may limit root mortality and consequently sprouting potential. The chemical does not concentrate in the roots, but instead travels to the upper portions of the plant. The specific mechanism of action is unknown, but it is thought to be a photosynthetic inhibitor (Weed Science Society of America 1983).

In Canada, silvicultural use of hexazinone is registered only for ground application. It is available as Velpar® L. (25% active ingredient), a water dispersible liquid, or Velpar® (90% a.i.), a soluble powder. Gridballs®, a pelletized form of hexazinone, have been discontinued by the manufacturer. Pronone®, distributed by Pfizer Ltd. of Windsor, Ont., is also a pelletized form of hexazinone. It is being field tested before registration (Sutton 1986). The pellets are often dispersed in a grid formation to maximize effectiveness.

Pelletized forms of the herbicide need no special equipment for application, and this minimizes delays. Drift, associated with aerial application, does not occur. If applied by hand, the pellets can be positioned precisely. This facilitates relocation or removal in the event of a mishap or miscalculation (Sutton 1986).

However, concern over herbicide mobility in the soil was mentioned by a number of questionnaire respondents. High clay or organic matter content in the soil reduces movement because of the high cation exchange capacity (Neary *et al.* 1983). Adequate soil moisture is required to activate Velpar® in the soil. Velpar® L. is not to be used on gravelly, rocky, sandy, or frozen soils, or on exposed subsoil. Application onto compacted surfaces or ditches increases the chance of off-site movement.[18]

3.1.2.1 Treatment effects

Aspen mortality Aspen mortality rates vary according to treatment timing, dosages, clonal resistance, rainfall after treatment, temperature, soil moisture and care in application. Information tabulated from the respondents about aspen mortality by hexazinone treatments is given in Table 3. As in Table 1, measures of success used are subjective, based on operational work and not on controlled experiments.

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18 Geisler, M. and F. Newhouse, 1987. Preliminary observations of Velpar® L. movement within the Prince Rupert Forest Region. Forest Service Internal Report PM-PR-9. J. Henigman (editor). Protection Branch, B.C. Ministry of Forests, Victoria, B.C.

TABLE 3. Rate and success of operational Velpar® treatments

Source	Chemical	Rate	Date	%Success yr 1	Measure of success
BCFP	Velpar® Screef & squirt	1 mL/10 cm dbh applied in four spots within 30 cm of the stem base	86	70	year 1 kill
BCFP	Velpar® Spear technique	1 mL/10 cm dbh applied in four spots within 30 cm of the stem base	86	70	year 1 kill
LAKELAND	Velpar® Spears	1 mL/per 1 cm dbh	May 86,87	very poor	lack of residual tree mortality too soon to tell if suckers will die
LAKELAND	Velpar® Spears not screefed	1 mL/per 1 cm dbh	May 86,87	very poor	lack of residual tree mortality too soon to tell if suckers will die

BCFP: Fletcher Challenge Canada (formerly British Columbia Forest Products)

In an Ontario study, aspen was found to be highly susceptible to Gridball® (Sutton 1986). The treatment was applied in mid-June at three locations. At one site in plots treated with .91-m spacing of Gridballs, aspen approximately 10 m tall lost most of their foliage within a month. Not all aspen died as a result of the treatment, but survivors had low vigor over the 7-year observation period. No sprouting was observed in the treated area.[19]

There is no mention on the Velpar® label for its use as a pre-harvest treatment. However, it can be used as an undiluted spot treatment for deciduous brush control, but only on the following conifer species: balsam fir, black spruce, white spruce, and red pine. The label instructs that Velpar® L., undiluted, be applied to thawed soil in the spring or early summer. Application is by an exact delivery hand-gun applicator (a spot gun). The manufacturer suggests the use of 0.75-1.5 mL of Velpar® for each centimeter of dbh of plants to be controlled. The treatment is to be applied as close as possible to the root collar of the target–within 0.5 m is recommended. Where multiple applications are required, it is suggested that they be made around the circumference of the plant, at points at least 1 m from desirable conifers. Best results occur when the soil is moist at the time of application and 0.6-1.2 cm of rainfall occurs within 2 weeks after application.[20]

Studies by the manufacturer found spot gun applied hexazinone resulted in 90-100% defoliation of young aspen within 2 years of treatment on a variety of sites (Expert Committee on Weeds 1985).

Timing Interval The period of time for the treatment to kill the aspen and limit root sprouting has been estimated at between 1 and 2 years,[21] and at greater than 4 years.[22]

19 Sutton, R. Canadian Forestry Service, Great Lakes Forestry Center, Sault Ste. Marie, Ont., pers. comm., March 1988.
20 Velpar® L. Label instructions, DuPont Canada Inc.
21 Zak, B. Forester, B.C. Forest Products, Mackenzie, questionnaire response.
22 Casteel, J. Manager Forestry and Engineering, Lakeland Mills, Prince George, questionnaire response.

Seasonal timing The label specifies late spring/early summer for effective control. Later application dates have not been assessed. The Provincial Pesticide Control Branch restricts use after July 31 as a permit stipulation.[23]

Aspen sprouting As discussed previously, aspen predominantly regenerates by sprouting after canopy removal, unless the roots have been killed. Sutton found that aspen saplings did not resprout after treatment with Gridballs.[24]

Ground and stream water quality Of the three main treatments, hexazinone was perceived by the questionnaire respondents as having the greatest risk or impact on ground or stream water quality. Seventy-one percent of the respondents thought there was a medium chance of risk or impact to water quality, 24% indicated a high probability, and only 5% suggested a low probability. These perceptions may limit Velpar® use from areas where water quality is a sensitive issue.

The concerns raised by respondents on risks to water stemmed from reports of off-site movement which have been observed in operational use. For example, Pollack stated that he had seen off-site movement of spot gun applied hexazinone on several sites in the SBSe between 1984 and 1986.[25] The incidents occurred on luvisolic soils of varying textures at 4-11 mL/spot rates for both spring and fall applications. Geisler and Newhouse found movement away from the point of application on a number of sites with different soil conditions and application rates.[26] They provide a number of recommendations to reduce off-site movement.

Soil characteristics Hexazinone (Velpar®) is a soil-active, mobile herbicide which is readily leached in coarse soils, but not through organic layers (Feng 1987). In photodegradation studies on thin soil surfaces, 60% was degraded during a 6-week exposure to UV light (Weed Science Society of America 1983). However, microbial action is thought to be the primary mode of decompositon, with the soil half-life being anywhere from 1 to 6 months (B.C. Ministry of Forests 1987). Feng (1987) found approximately 66% degradation in 3 months after application in silt loam soils.

Rhodes *et al.* (1980) did not find hexazinone to reduce or modify soil fungus populations at its expected use rates.

Questionnaire respondents considered this method to have the highest risk or impact of the three methods assessed (Fig.3) The range of responses (16% - low; 58% - medium; and 26% - high) is most likely a result of different information bases, which could affect use.

Post-harvest conifer crops The effect of the treatment on post-harvest conifer crops depends on the longevity of the chemical and the post-harvest species selection. If the Velpar® treatment is done just before logging, or in the same year, species such as lodgepole pine and Douglas-fir should be evaluated carefully for local susceptibility. This could potentially limit Velpar® use on such sites. However, recent studies indicate that Douglas-fir and lodgepole pine are more tolerant than initially thought.[27] Further testing is warranted.

Questionnaire respondents indicated that hexazinone had the highest perceived risk or impact of the three methods assessed on conifer crops. Respondents also indicated that there was less information available on this subject than on most, making informed decisions more difficult.

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23 Balfour, P. B.C. Ministry of Environment, Pesticide Control Branch, pers. comm., 1988.
24 Sutton, R. pers. comm., April 1988.
25 Pollack, J. Research Officer, B.C. Ministry of Forests, Prince Rupert Forest Region, questionnaire response.
26 Geisler and Newhouse. 1987.
27 Expert Committee on Weeds 1987, p. 353.

Wildlife and wildlife habitat The effect of hexazinone-treated stems on wildlife habitat has not been determined and warrants study.

In addition, hexazinone is a soil-active non-specific herbicide, that may reduce levels of preferred browse species such as willow.

Questionnaire respondents perceived Velpar® as having the highest probability of risk on wildlife and wildlife habitat (Fig. 5), yet indicated there was little information on which to base those opinions.

Worker safety The manufacturer's safety precautions for Velpar® state:

Do not get in eyes. Avoid breathing vapors or mist. Avoid contact with skin. Avoid contact with clothing. (DuPont 1986).

Questionnaire respondents' risk perception for Velpar® use was similar to that indicated for stem injection (Fig. 6).

3.1.2.2 Demonstrations of hexazinone treatments

Hexazinone has had limited operational use in B.C. The following table lists areas treated for pre-harvest aspen control.

Agency	Location	Size (ha)	Year treated
BCFP	Mackenzie	141	1986
BCFP	Mackenzie	100	1986
Lakeland	Prince George	?	May 1986, 87

BCFP: Fletcher Challenge Canada (formerly British Columbia Forest Products).

3.1.2.3 Operational guidelines

Respondents offered no specific recommendations on hexazinone application. Season of application was limited by Ministry of Environment policy, as suggested by label instructions. Most respondents indicated there was a medium probability of risk or impact for the variables assessed, except for worker safety. These perceptions of risk may limit its use in certain situations.

3.2 Manual Treatments

3.2.1 Girdling

Girdling is the process of removing bark and cambium from around the stem, thereby blocking carbohydrates from reaching the roots. This starves the roots and kills the plant. The depth of the girdle determines which of the functional elements of the tree are severed. Deep girdles not only remove the phloem and cambium, but they can also cut into the xylem which is the water-conducting system. Deep girdles mimic stem severing and therefore may negate the desired effect of reducing the cytokinin auxin ratio. Fig. 7.

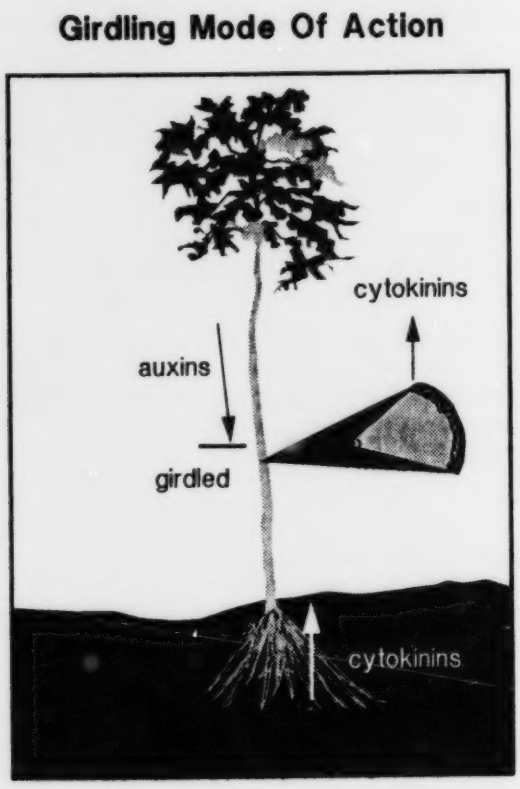


FIGURE 7. The effect of girdling on cytokinin and auxin movement.

Girdling can be performed with a number of hand or power tools. Axes, hatchets, Sandviks, and machetes were some of the hand tools used in the past. Each was functional but slow. More specialized and efficient tools are now being developed or revived. The Vrendenburg girdler, a plier-like tool with teeth on the inner surface, girdles the stem by being rotated approximately 90°. Modern chain girdlers, patterned after those developed in the 1950's, are more efficient and easier to use.

Chainsaws have also been used to girdle stems and are favored by some workers (Whitehead 1982). Cavanagh and Weyrick (1978) proposed the use of weed burners to girdle stems. The technique has been tested on aspen and other deciduous species, and preliminary findings show it to be as effective as mechanical girdling. On thin bark species such as aspen, the heat completely girdles or damages the cambium in approximately 5-10 seconds. Periods of high forest fire hazard would limit use.

Each tool has advantages and disadvantages. Modern manual girdling tools, other than chainsaws and axes, are non-polluting and safe to operate, and do not require herbicides to be effective. No cumbersome protective gear need be worn by the operator, except in the case of chainsaw use, where chaps, face shields, and ear protectors are recommended. For the non-motorized tools there is no risk of hearing impairment or debilitating disease such as "white hand" which is linked to chainsaw use (Conway-Brown 1986). (However, the repetitive movements associated with girdling can result in a condition known as tenosynovitis, a painful inflamation of a tendon). Manually controlled girdling devices use muscle power, and therefore require physically fit operators. Stem size also restricts the use of some tools. The Vrendenburg girdler, for example, is limited to stems between 2.5 and 15 cm (Conway-Brown 1986).

Girdling does not require 10 m streamside buffers as pesticide permits do, but consultation with Fish and Wildlife or Fisheries staff should be done before streamside alterations are made. Nor are any permits, extensive management procedures, or any herbicide storage facilities needed, thus reducing overhead costs. As well, no appeals or court cases are likely to occur from girdling operations as a result of accidental permit violations or public reaction to the method–thus, no special training or public involvement programs are necessary.

Cody and Burns (1976), in an evaluation of chainsaw girdling to treat unwanted northern hardwoods, reported that the cambium must be completely severed for the girdle to be effective; overlapping the end cuts is not sufficient. They found that incomplete girdles often occurred at cracks, seams, flutes, and callus growth. Complete girdles are a must for effective control.

3.2.1.1 Treatment effects

Aspen mortality Aspen mortality may be a result of treatment timing, clonal resistance, and care in application. Information tabulated from the respondents about aspen mortality by girdling is given in Table 4. Measure of success is subjective, based on operational observations and not on controlled studies.

TABLE 4. Success data of aspen girdling

Source	Tool	Date	%Success				Measure of success
			yr 1	yr 2	yr 3	yr 4	
Crown	Axe	May-Oct 83				89	Death of treated stems
BCFS	Vrendenburg	Aug 85	0				Defoliation after 1 yr
Foster	Chain girdler	June 87	100				No sprouting or stem bridging after 1 season

Source: Questionnaire responses

Noel (1965 cited in Noel 1970) found that, except for very narrow girdles, the width is not directly related to the efficacy of killing. He suggested that wide girdles are more effective in decreasing the chance of girdle bridging when girdling is inefficiently carried out.

Waldron (1961) assessed the effects of two girdling treatments and two chemical treatments on aspen mortality. He found that all methods resulted in complete mortality of the treated trees within 4 years.

Timing Interval Little local information on timing and effectiveness of girdling is available. The following table summarizes what information is available. Johansson (1985) indicated that girdling must be done 10 years before final felling, but he offered no studies or data to substantiate his recommendation.

Source	Period required for top kill of aspen
Schier and Smith (1979)	1-3 years
Brown (1963, cited in Noel 1976)	1 year
Waldron (1961)	3-4 years
Crombie (1965)	3 years

Seasonal timing Clark and Liming (1953) suggest that the most effective time to girdle is when root reserves are lowest, which is during the period of active growth. In aspen stands of southern British Columbia this occurs in early spring. Schier suggested the best time to girdle would be just before leaf break, to take advantage of low root reserves.[28]

Aspen sprouting In a study of sucker regeneration in a Utah aspen clone, Schier and Smith (1979) found that girdling all the aspen on a site initially stimulated suckering. Initial mortality after girdling was high, with only 6% of the initial suckers alive after 4 years. After 12 years, the girdled site had only 307 (1m or greater) suckers per hectare, versus 14 320 on the clearcut site. The hypothesis was that girdling weakened the root systems to such an extent that sucker survival was reduced dramatically.

Suckering occurs as a natural component of aspen stands (Fig. 8). The girdled stems had an initial increase in sucker production, likely due to a slight initial increase of the cytokinin auxin ratio. However, the rate of suckering was still much lower than on the cut site, because the cytokinins still flow relatively freely upwards (Schier and Smith 1979).

Schier and Smith (1979) suggest that high sucker mortality was caused by the rapid deterioration of roots of the girdled stems. Tree tops remained alive for 1 to 3 years, depleting the roots of reserves.

Crombie (1965) in an Ontario study, found 100% mortality and no sprouting in aspen 3 years after girdling within a mixed stand. The treated portion of the stand varied from between one-quarter to one-third of the total basal area. He tested three methods of girdling: a double frill with two rows of overlapping downward axe cuts, 7.5 - 10 cm apart; a single frill of overlapping downward cuts; and a notch girdle, which is a continuous V notched out of the bark, exposing the xylem. The cost and difficulty of applying each method varied significantly. Single frills, the cheapest method, were done incorrectly 9% of the time compared with less than 3% for the double frill or notch girdle which had similar costs. Crombie indicated that older trees with furled bark may require a chainsaw to provide adequate girdles.

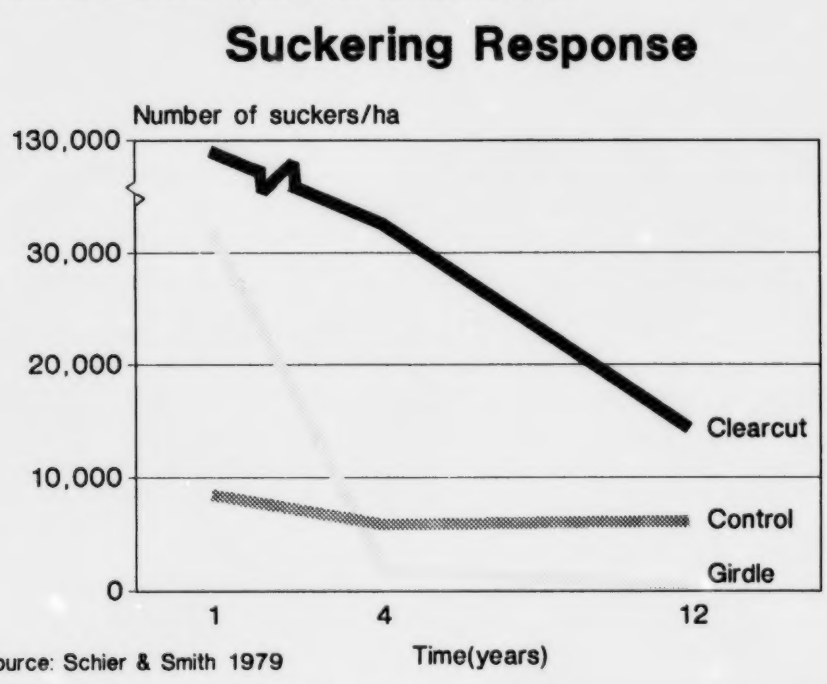
Size of stem may also have an effect on sprouting. Clark and Liming (1953) found that as tree diameter increased, the percent of sprouting decreased for blackjack oak. They also found waist-high girdles to be more effective than those made at 15 cm from the ground. The importance of these factors to the effectiveness of aspen girdling needs to be addressed.

Ground and stream water quality There is no appreciable reason why pre-harvest girdling of aspen would change ground water or stream water quality.

Soil characteristics The effect of pre-harvest girdling of aspen on soil characteristics will likely be minimal because aspen is a minor component in a pre-harvest treatment stand.

28 Schier, G. Principal Plant Physiologist, Northeastern Forest Experiment Station, Forestry Sciences Laboratory, Delaware, Ohio. pers. comm., March 1988.

Questionnaire respondents were divided between feeling there is low probability of a risk or impact and that the issue is not applicable for the treatment type.



Source: Schier & Smith 1979

FIGURE 8. Sucker response to clearcutting and girdling in a pure Utah aspen stand - 12 year results.

Post-harvest conifer crops A B.C. Ministry of Forests study found that girdling had no appreciable effect on aspen after 1 year.[29] The study suggested that there would be a high risk of impact on the post-harvest conifer crop due to severe seeding-in, caused by stress in the aspen, or by resprouting. Seeding-in is not likely a major source of regeneration (see Section 2.1). The area assessed was girdled in August which would result in less than optimal results as root reserves have been replenished. For sites girdled in the late summer or fall a 2-year minimum response time should be given prior to assessment.

Questionnaire respondents felt there was a low probability of negative effects on post-harvest crop species. This value was lower than that for both other assessed treatments (Fig. 4).

Wildlife and wildlife habitat As in the earlier discussion, the period of decay after death to the main stem is a concern for wildlife habitat.

Presently there are no studies that have assessed the effect of aspen girdling on wildlife or wildlife habitat. Direct effects on wildlife due to girdling were not thought to be a problem by those polled. The probability of risk or impact was felt to be lowest for girdling compared to that for the other two treatments (Fig. 5).

Worker safety Worker safety depends on a number of factors. Any sharp instrument can cause injuries if it is used improperly.

Improper use of chainsaws and axes can result in cuts and lacerations to the legs. Risk of injury increases with the level of fatigue, which relates to personal stamina, terrain conditions, stem size, and density. Girdling tools such as the Vrendenburg girdler are comparatively safe to

29 Ackerman, G. Questionnaire response.

operate and so risk of injury is restricted to the natural hazards of working in the forest. Chainsaw blades adapted as girdling tools are safer than the motorized version, but must be used carefully.

Questionnaire respondents indicated that girdling had the highest probability of risk or impact for the worker compared to that for the other assessed treatments (Fig. 6). This shows that safety training should be a critical component for girdling as well as for the other treatment methods.

3.2.1.2 Demonstrations of available treatment methods

Few operational examples of girdling aspen exist. The ones reported are as follows:

Agency	Location	Size (ha)	Year treated
Crown Forests	Kelowna	10	1983
BCFS	Victoria	0.5	1985
Riverside	Lumby	179	1987
BCFS	Kamloops	45	1987

Addresses of the above agencies are given in Appendix 2.

3.2.1.3 Operational guidelines

Complete girdles that sever the cambium are required for effective control. Girdling tools should be chosen for the specific stand. Girdles 1.9 cm wide, penetrating 0.3 cm into the sapwood and encircling the stem, are recommended. Girdling in the spring is best, as a full growing season of carbohydrates is obstructed from the roots. One questionnaire respondent suggested that spring or early summer girdling is the most effective time as there is an increase of carbohydrate accumulation in the foliage, resulting in increased shading and poorer sucker survival.[30]

The number of years required between treatment and harvest to provide adequate sucker reduction is unknown. Estimates vary from 1 to 10 years. Studies indicate that 1 to 3 years for top death is common (Brown 1936; Crombie 1965; Schier and Smith 1979; Waldron 1961). Crown death shows that root reserves are depleted, restricting further suckering potential. Experimentation to determine the optimum interval between treatment and harvesting is needed.

3.3 Alternatives

No other operational methods were recommended by questionnaire respondents.

However, helicopter application of glyphosate to single trees or clones was suggested by Newton as a pre-harvest method.[31] This is being done in Oregon on bigleaf maple *(Acer macrophylum)*, using triclopyr. Since this treatment has never been performed either experimentally or operationally, it was not assessed along with the three main treatment options.

30 Foster, J. Questionnaire response.
31 Newton, M. pers. comm. 1988.

4 PRODUCTIVITY AND COST COMPARISONS

The productivity of any stem- or land-based treatment depends on a variety of factors such as severity of terrain, stem size, stem density, specifications of treatment, crew experience, weather, and many other factors. In evaluating the relative productivity of two treatments, Hedin (1983) found that for diameter classes between 4 and 16 cm, girdling with a chain girdler was significantly faster than hack and squirt. For trees greater than 16 cm–those usually found in pre-harvest treatments–there was not a large enough sample to provide statistically significant results. Girdling appeared to be slightly slower than hack and squirt: the average time to girdle a stem greater than 16 cm was 0.91 minutes (calculated from 20 timed stems) compared to 0.67 minutes (on 5 timed stems) for hack and squirt. Crew experience could significantly affect this result.

Costs for six treatments were calculated per diameter inch by Crombie (1965). His results are shown in Table 5.

Larger aspen with thick uneven bark will likely require greater time, and hence greater cost per tree, to provide adequate girdles.

Questionnaire responses on girdling costs ranged from $0.10 to 0.65 per stem. These costs are substantially below those given for injection, which ranged from $0.72 to 3.00. The costs for hexazinone injection were not available on a per-stem basis, but were thought to be comparable to other injection techniques.

Crombie's results indicate girdling is cheaper than herbicide injection for the dbh range studied. Bancroft (1987) found no appreciable difference in operational costs of hack and squirt versus girdling for conifer release from red alder in three coastal British Columbia forest districts. Costs will likely vary by stem size and density, locality, contractor availability, and contractor preference.

TABLE 5. Costs of various control treatments

Treatment	Weighted average dbh (cm)	Cost per diameter inch (¢)
Notch	11.7	.57
Double Frill	11.9	.59
Single Frill	12.2	.46
Partial Frill	10.9	.34
Single Frill with 2,4,5-T	8.9	.78
Partial Frill with 2,4,5-T	9.4	.51

Source: Crombie 1965.

Waldron (1961), in comparing costs per stem of two girdling techniques and two herbicide methods for killing aspen, determined that girdling by the Handi-girdler was the most economical method. The study was done under non-operational conditions and used 1960 wage and material costs.

TABLE 6. Cost comparisons of manual vs chemical methods of control treatments

Treatment	Cost per stem (¢)
2,4,5-T as a basal bark spray	13
2,4,5-T in basal frills	7
Girdling at breast height (axe)	8
Girdling at breast height (Handi-girdler)	5

Source: Waldron 1961.

Huckenpahler (1954), in a study comparing poisoning to girdling to release underplanted pines in Mississippi, calculated that girdling was more productive than herbicide injection. Girdling averaged 2.2 minutes per stem versus 3 minutes per stem for herbicide injection of similar diameter and density.

5 CONCLUSIONS

The information collected shows that each of the three treatment types discussed can be effective in achieving pre-harvest aspen control. However, no studies offer conclusive results about the best timing between treatment and canopy removal to limit post-harvest suckering.

Operational personnel suggest that a period of 2-10 years between treatment and harvest is required for effective control. A 3-year interval is now being used operationally. Available information on aspen physiology and control methods suggests that successful control may be possible in less time. Further studies are required to determine the effect of time between treatment and harvesting on aspen suckering.

For operational planning, however, timing between control and harvest is often a problem, because of lack of access or because of cutting plans altered as a result of insect infestation. Waiting for 3 years or longer after aspen treatment to harvest the stand may not be an operational option.

There is some evidence that suckers formed from roots of treated stems will die at a higher rate, years after treatment, than suckers from untreated stems. This type of information can only be obtained from long-term studies. The implications are potentially very useful, as less time between control and harvest may be possible. It is therefore suggested that any experimentation on pre-harvest control have follow-up assessments 5 and 10 years after canopy removal. Permanent plots, put in before control and assessed for sucker density before and after harvest, are required.

Questionnaire respondents indicated that the probability of risk or impact was highest with ground application of herbicide, except for worker safety (Figs. 3-6) Actual risks or impacts depend on site-specific situations.

Available information shows that girdling may be as effective as (and possibly less expensive than) the two herbicide techniques discussed. However, the period of time required for effective control between treatment and harvest may be longer for girdling than for the chemical treatments. Therefore, to optimize the cost of pre-harvest aspen control in British Columbia, experiments to determine suitable pre-harvest timing and resultant suckering response are required.

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APPENDIX 1. QUESTIONNAIRE

CAN ASPEN REGENERATION IN THE SOUTHERN INTERIOR BE REDUCED BY PRE-HARVEST TREATMENTS? A LITERATURE REVIEW
FRDA PROJECT 3.60

QUESTIONNAIRE

What is your experience with pre-harvest aspen control? Please give a brief description of your position and years of experience with pre-harvest aspen control.

A. NONE - Please go to Section 2

B. OPERATIONAL - Please fill in both Sections 1 & 2

C. ADMINISTRATIVE - Please fill in both Sections 1 & 2

SECTION 1. TREATMENT DETAILS

1. What operational methods have you used? Please fill in the table below. Examples are provided to indicate information desired.

METHOD	TYPE OF CHEMICAL	RATE	AREA TREATED	TIME	%SUCCESS*
girdling	N/A	N/A	50 ha	June 86	?
hack & squirt	Roundup	2.5 ml [100%] per 5 cm dbh	50 ha	Aug 84	90%

* By what method was success judged? For example less than 10% sprouting, total kill . . . and over what time period was success judged.

2. What time frame is considered necessary for successful control prior to harvesting? (by treatment type).
   Please state the source of information - for example local results, or a particular article or personal communication.

3. Is season of control considered to be a factor, if so

   a) in what season is the greatest control achieved? (by treatment type)

   b) in what season is the least control achieved? (by treatment type)

   c) source of information

4. What was the cost per ha by treatment type? Please provide the following information for comparison purposes:

Treatment	Stems/ha	Ave dbh (cm)	Area (ha)	Yr	Cost/ha ($)	Comment
Hack & squirt	58	25	50	84	45	easy terrain

5. Please provide any general comments regarding the various control methods used. For example, the use of anti-freeze with glyphosate to increase winter effectiveness.

6. From your experience do you think pre-harvest aspen control is a cost effective treatment method? Please give reasons for your answer.

SECTION 2. TREATMENT SIDE-EFFECTS

This section examines specific side-effects of various treatments. An objective is to pinpoint areas of limited information.

In the following section we would like you to comment on 2 factors:

1. Available information
2. Probability of risk or impact

Please scale each factor from 1 to 3 using the following correlations:

1 - N for negligible data
2 - S for some data
3 - A for abundant data

1 - L for low probability of risk or impact
2 - M for medium probability of risk or impact
3 - H for high probability of risk or impact

Please answer to the best of your knowledge the effects on the following variables by treatment type:

1. Ground water and stream water quality

	Hack and Squirt glyphosate	Girdling	Spot gun velpar	Other (specify)
Information (1,2,3)				
Risk/Impact (1,2,3)				

Comments:

2. Physical, chemical, and biological characteristics of the soil

	Hack and Squirt glyphosate	Girdling	Spot gun velpar	Other (specify)
Information (1,2,3)				
Risk/Impact (1,2,3)				

Comments:

3. Post harvest conifer crops

	Hack and Squirt glyphosate	Girdling	Spot gun velpar	Other (specify)
Information (1,2,3)				
Risk/Impact (1,2,3)				

Comments:

4. Wildlife and wildlife habitat

	Hack and Squirt glyphosate	Girdling	Spot gun velpar	Other (specify)
Information (1,2,3)				
Risk/Impact (1,2,3)				

Comments:

5. Safety of forest workers applying treatment

	Hack and Squirt glyphosate	Girdling	Spot gun velpar	Other (specify)
Information (1,2,3)				
Risk/Impact (1,2,3)				

Comments:

Thank you again for your time and knowledge.

APPENDIX 2. QUESTIONNAIRE RESPONDENTS

	Operational Information on:		
	Injection	Velpar®	Girdling
Brian Zak B.C. Forest Products Box 310 Mackenzie, B.C., V0J 2C0 997-3271	YES	YES	NO
Don Roy Forestry Supervisor Canadian Forest Products P.O. Box 6000 Prince George, B.C., V29 2K3 563-0161	YES	POST LOG	NO
Lloyd Manchester Earthcare Society 539 Radant Road Kelowna, B.C., V1W 1A1 764-4277	NO	NO	NO
John Foster Box 23 Clearwater, B.C., V0E IK4 674-3330	NO	NO	YES
Tim Salkeld Integrated Silviculture Services 4184 15th Avenue Prince George, B.C. 564-9299	YES	NO	NO
John Casteel Manager, Forestry and Engineering Lakeland Mills P.O. Box 1358 Prince George, B.C., V2L 4V4 564-6810	YES	YES	PINE
Norm Crist Manager Silviculture and Nurseries Northwood Box 9000 Prince George, B.C., V2L 4W2 962-9611	YES	NO	NO
Dr. Jacob Boateng Vegetation Management Specialist Silviculture Branch 31 Bastion Square Victoria, B.C., V8W 3E7 387-8905 (Answered by G.Ackerman)	YES SX TRIALS	NO	YES
Michael Conway-Brown RR #3 No-Chem-Do Contractors Upper Zilinsky Road Powell River, B.C., V8A 5C1 487-9744	NO	NO	NO
Shane Browne-Clayton Crown Forests 820 Guy St. Kelowna, B.C., V1Y 7R5 762-3411	YES	NO	YES

QUESTIONNAIRE RESPONDENTS: (Continued).

	Operational Information on:		
	Injection	Velpar®	Girdling
Steve Knowles Finlay Forest Products Box 250 Mackenzie, B.C., V0J 2C0 997-3201 (Answered by Doug Perdue)	YES	NO	NO
Ken Hodges Ministry of Forests and Lands Prince George West District 1600 Third Ave. Prince George, B.C., V2L 3G6 565-6261	NO	NO	NO
Chris Thompson Research Officer Nelson Forest Region 518 Lake Street Nelson, B.C., V1L 4C6 354-6274	NO	NO	NO
John Pollack Forest Research Officer Prince Rupert Forest Region 3726 Alfred St. Bag 5000 Smithers, B.C., V0J 2N0 847-7436	NO	NO	NO
Ordell Steen Research Ecologist Cariboo Forest Region 540 Borland St. Williams Lake, B.C., V2G 1R8 398-4406	NO	NO	NO
Mike Dunbar Forestry Superintendent Houston Forest Products Box 5000 Houston, B.C., V0J 1Z0 845-2322	YES	NO	NO
Don Couch Silvicultural Forester Riverside Forest Products RR #2 Lumby, B.C., V0E 2GO 547 2111	YES	NO	YES
Brent Olsen Resource Officer Silviculture Kamloops Forest District 1255 Dalhousie Pl. Kamloops, B.C., V2C 5Z5 372-5832, 262	YES	NO	NO
Charles von Hahn Resource Officer Silviculture Vanderhoof Forest District Box 190 Vanderhoof, B.C., V0J 3A0 567-6363	YES	NO	NO

QUESTIONNAIRE RESPONDENTS: (Concluded).

	Operational Information on:		
	Injection	Velpar®	Girdling
Bruce Pamplin Stand Tending Coordinator Silviculture Prince George Region 1011 4th Ave. Prince George, B.C., V2L 3H9 565-6179	NO	NO	NO
Dr. George Schier Plant Physiologist NE Forest Sciences Lab USDA Forest Service 359 Main Rd. Delaware, Ohio, 43015 (614) 369-4471	NO	NO	YES
Dr. Donald Perala Plant Physiologist Forest Science Lab USDA Forest Service 1831 Hwy 169 E Grand Rapids, Minnesota, 55744	NO	NO	NO

Response rate 88% (22/25)

APPENDIX 3. PEOPLE CONTACTED

List of people contacted by phone or in person who were not sent a questionnaire:

Everett Peterson - Western Ecological Services

Tom Sullivan - Mammal Pest Management Ltd.

Michael Newton - Oregon State University

Gus Steneker - CFS Ottawa

Fred Newhouse - MOFL Smithers

Carol Anderson - Weyerhaeuser Canada Ltd. Kamloops

Rod Willis - Weyerhaeuser Canada Ltd. Armstrong

Ingrid Davis - MOFL Merritt

Wayne Coombs - CFS Victoria

Sue Watts - UBC

Caroline Caza - UBC

Dave Winegartner - Ministry of Natural Resources, Ontario

Harry Anderson - Ministry of Natural Resources, Ontario

George Krumlik - MOFL Victoria

Dr. John Smith - Senior B.C. Provincial Medical Consultant

John Zasada - USDA Forest Service Oregon

Wayne Biggs - Westland Resource Group

Mike Carlson - MOFL Vernon

Phil Comeau - MOFL Victoria

Roy Sutton - CFS Sault Ste. Marie, Ontario

Andrew Harcombe - MOEP Victoria

Patty Balfour - MOEP Victoria

John Henigman - MOFL Victoria

APPENDIX 4. TOXICOLOGICAL INFORMATION

GLYPHOSATE

The toxicological data from Monsanto on Vision® (Roundup®) are as follows:

Oral LD50 (rat)	5400 mg/kg, practically nontoxic
Dermal LD50 (rabbit)	>5000 mg/kg, practically nontoxic
Eye irritation (rabbit 24 hr)	FHSA score 4.1/110 - slightly irritating
Skin irritation (rabbit 24 hr)	FHSA score 4.3/8 - moderately irritating
Inhalation LC50 (rat 4 hr)	3.18 mg/L (analytical concentration) slightly toxic
96 hour LC50 Rainbow Trout (flow through):	8.2 mg/L, moderately toxic

Source: Monsanto material safety data, 1987.

2,4-D

Toxicological data from Dow on Formula 40 weed killer (active ingredient 2,4-D amine)

Oral LD50 (rat)	1000-2000 mg/kg
Eye irritation	causes burns
Skin irritation	causes irritation
Inhalation	no guideline established
Systemic and other effects	nausea and vomiting

Source: DOW material safety data sheet, 1987.

HEXAZINONE

Toxicological data for Velpar® are as follows:

Oral (rat) LD50 is 6887 mg/kg practically nontoxic
Dermal (rabbit) LD50 is greater than 7500 mg/kg practically nontoxic

Not teratogenic or embryo-fetal toxic to rats at 5000 ppm or to rabbits at 125 mg/kg per day

Causes eye damage with contact.

Source: Du Pont material safety data sheet for Velpar®.

APPENDIX 5. SELECTED ANNOTATED REFERENCES

Basham, J.T. 1982. Effects of herbicide treatment on the internal pathological quality of surviving aspen suckers. Canadian Forestry Service, Information Report 0-X-334. Great Lakes Forest Research Center, Sault Ste. Marie, Ontario. 26 p.

Annotation: The study provides an assessment of aerial spraying of 2,4-D and 2,4,5-T to control aspen. Treated aspen had extensive top-kill and reduced diameter increment for 2 years following spraying. The root rot fungus *Armillaria mellea* was found to be more common in root systems of sprayed than unsprayed suckers. Despite the initial height and diameter setbacks, surviving suckers resumed normal growth. The higher incidence of root rot in the treated plants is of some concern and warrants further investigation.

Cavanagh, J.B. and R.R. Weyrick. 1978. Weed burner for controlling undesirable trees and shrubs. Journal of Forestry 76: 472-473.

Annotation: Cavanagh and Weyrick show the utility of a backpack mounted weed burner for girdling hardwoods. Numerous species were treated, including aspen. Preliminary evaluation found it to be effective at destroying the cambium. It appears to be a relatively easy and fast method of girdling, taking anywhere from 5 to 30 seconds per stem, depending on stem size and bark thickness. Its use would be limited in times of high fire hazard.

Clark, F.B. and F.G. Liming. 1953. Sprouting of blackjack oak in the Missouri Ozarks. U.S. Department of Agriculture Forest Service, Central States Forest Experiment Station Technical Paper 137.

Annotation: The article, even though concerned with oak rather than aspen, is relevant because it details the effects of girdle depth to suckering. This information was not found elsewhere for aspen, making it a factor of interest in any girdling trials. Stems with girdles not severing xylem tissue were found to have greater sucker mortality and shorter suckers than notch-girdled stems.

Cody, J.B. and K.F. Burns. 1976. An evaluation of chain saw girdling to treat unwanted northern hardwoods. State University of New York, College of Environmental Science and Forestry, Applied Forestry Research Institute, Research Report No. 29.

Annotation: This article details the results of girdling trials with and without the addition of herbicide. They concluded that if the girdles were complete, chemicals were not required for effective control. Aspen was not a target species.

Conner, R.N., J.C. Kroll, and D.L. Kulhavy. 1983. The potential of girdled and 2,4-D injected southern red oaks as woodpecker nesting and foraging sites. Southern Journal of Applied Forestry 7(3): 125-128

Annotation: The article indicates possible secondary effects of chemical control versus girdling. In this study, chemically treated oaks decayed faster, resulting in reduced woodpecker habitat. Decay rate is also of importance to worker safety but was not addressed.

Conway-Brown, M. 1986. Girdling - A non-toxic control for red alder. The IPM Practitioner, VIII (10): 1-7.

Annotation: This is a good article to aquaint those not familiar with modern girdling techniques. Conway-Brown provides information on productivity, costs, limitations, worker acceptance, and girdling specifications.

Crombie, G.N. 1965. The effectiveness and costs of various treatments to eliminate undesirable hardwoods. Ontario Department of Lands and Forests, Silvicultural Notes No. 1.

Annotation: Crombie's study evaluated six deciduous control treatments. He assessed notch girdling, double frill, single frill, single frill with 2,4,5-T, partial frill with 2,4,5-T, and partial frill. All girdling treatments, including the herbicide option, resulted in 0% suckering of aspen. As well, 98% of the stems treated were dead after 4 years. Partial frill, with or without herbicide, resulted in less than 50% mortality. Treatment costs and mechanical error were also assessed. The treated stems made up approximately one-quarter to one-third of the basal area of the stand. There was no indication that the conifer component was removed after treatment. The study is one of the few that assessed girdling of aspen. It demonstrated that proper girdles are effective at controlling both top-kill and suckering of aspen when done in a mixed-wood setting.

Eliasson, L. 1971. Growth regulators in *Populus tremula* IV. Apical dominance and suckering in young plants. Physiol. Plant 25: 263-267.

Annotation: Eliasson, in a series of articles, relates the effect of auxins in relation to sprouting in *Populus tremula*. This article explains the theory of apical dominance and repression caused by auxin levels. He postulates that auxins alone were not totally responsible for sucker response, as girdled stems had fewer and smaller suckers than severed stems. He indicated that cytokinin levels in the roots were also likely a factor for suckering. This information is the key to girdling being more effective than severing for sucker control.

Farmer, Robert E., Jr. 1962. Aspen root sucker formation and apical dominance. Forest Science 8: 403-410.

Annotation: Apical dominance in the form of the auxin indole-3-acetic acid (IAA) was shown to be a factor in sucker repression. Farmer found that 1-year-old stems girdled in the greenhouse formed suckers within 2 weeks, stems girdled in a natural setting did not form added suckers. The mechanism of added factors such as cytokinin production was not yet postulated. The study indicates that very young stems have a higher propensity to sucker. However, there is no information as to survival of the new suckers.

Garrett, Peter W., and Robert Zahner. 1964. Clonal variation in suckering of aspen obscures effect of various clearcutting treatments. Journal of Forestry 62: 749-750.

Annotation: Clonal variation of bigtooth aspen to various clearcutting treatments is shown to be in the order of six-fold. This has direct implications for experimental design. They suggest many replications to obtain conclusive treatment effects.

Hedin, I.B. 1983. A comparison of productivity of girdling and hack-and-squirt techniques in conifer release. Interim Report IR-383-2. Forest Engineering Research Institute of Canada. Vancouver, B.C. 8 p.

Annotation: In a time and motion study, girdling with a Vredenburg girdling tool was found to be significantly faster than conventional hack and squirt for stems 4-16 cm dbh. There was not a sufficient data base to assess larger stem sizes. This study is one of the few done in British Columbia relating the efficiency of girdling to injection methods. The study indicates that girdling efficiency depends on tool selection and stem size.

Maini, J.S. and K.W. Horton. 1966. Vegetative propagation of Populus spp. 1. Influence of temperature on formation and initial growth of aspen suckers. Canadian Journal of Botany 44: 1183-1189.

Annotation: Maini and Horton tested for the effects of temperature on suckering response. They provide evidence to suggest that temperature is a major factor in stimulating suckering independent of auxin concentration. They suggest that the extreme temperatures tested (14° and 35°C) somehow affect the initiation response, but they do not provide any specific physiological explanation. It is a useful paper, as it indicates that auxin levels themselves are not totally responsible for the suckering response.

Neary, D.G., P.B. Bush, and J.E. Douglass. 1983. Off-site movement of hexazinone in stormflow and baseflow from forest watersheds. Weed Science 31: 543-551.

Annotation: Neary *et al.* provide an examination of off-site movement of hexazinone from a Georgia watershed. They found the chemical to exhibit the typical residue delay curve with pulses which they attributed to leaf-fall events. The paper is informative but, because of different temperature regimes and the use of pelletized hexazinone, the results are not readily transferable to cooler sites and the use of liquid herbicide, which would be the case in our area.

Newton, M. and L. A. Norris. 1976. Evaluating short and long term effects of herbicides on non-target forest and range biota. Down to Earth, 32(3): 18-26.

Annotation: This paper provides an assesment of the use of herbicides and their effects on non-target organisms. It provides a clear statement of what are considered short- and long-term effects of herbicide treatments. The authors conclude that herbicide use must be viewed in comparison with available options, including doing nothing.

Noel, A.R.A. 1970. The girdled tree. Botanical Review 36: 162-195.

Annotation: Noel provides a comprehensive overview of the literature on girdling up to 1970. He provides numerous examples from temperate as well as tropical areas. The article emphasizes the variability of responses by species throughout the world. The extensive section on the physiology of the girdled tree outlines the many mechanisms involved in mortality through girdling. It is a useful reference on the subject.

Schier, G.A., J.R. Jones, and R.P. Winokur. 1985. Vegetative regeneration. *In* Aspen: ecology and management in the Western United States. N.V. Debyle and R.P. Winokur (editors). USDA Forest Service General Technical Report RM-119, 283 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Annotation: This article is one of many in the most up-to-date overall reference on aspen in North America. It covers all aspects of aspen management from physiology to markets. It is a very useful text and should be in the library of anyone managing aspen.

Schier, G.A. and A.D. Smith. 1979. Sucker regeneration in a Utah aspen clone following clearcutting, partial cutting, and girdling. USDA Forest Service Research Note INT-253, 8 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Annotation: Schier and Smith returned to a site 12 years after various aspen treatments to determine long-term sucker response. They found that girdled stems, while having an initially high rate of suckering (approximately one-quarter the rate of clearcutting), had very few surviving suckers after 12 years (approximately 300 per hectare, compared with 13 000 one year after treatment). The control had greater than 700 suckers on the site after 12 years. They hypothesized that the high sucker mortality, derived from girdled stems, was due to the rapid deterioration of the root system as a consequence of girdling. They suggest that shade from the girdled stems added to the mortality through unfavorable microsites. This information suggests that initial suckering numbers could lead to an overestimate of the competitive threat on sites treated by girdling.

Sutton, R.F. 1986. Hexazinone Gridballs applied with concurrent underplanting of white spruce in boreal mixedwoods: 7-year results. Forestry Chronicle 62(4): 226-232.

Annotation: Sutton provides information on the control of young aspen using Gridballs, a pelletized form of hexazinone. The treatment was found to be effective in controlling aspen.

United States Environmental Protection Agency. 1980. Summary of reported pesticide incidents involving glyphosate (Isopropylamine salt). Pesticide Incident Monitoring System Report No. 373.

Annotation: This document provides case reports of glyphosate exposure. The most severe symptoms appeared to be related to extensive dermal exposure or injestion. From the variety and severity of symptoms, it appears people have different susceptibility to the chemical.

Waldron, R.M. 1961. Girdling, basal spraying and frilling of mature aspen. Timber of Canada 22 (12): 34-35.

Annotation: Waldron compares four treatments for controlling aspen, including girdling with stem injections of 2,4,5-T and basal spraying of 2,4,5-T. Spring girdling was found more effective at killing aspen than late summer girdling. Both chemical treatments were faster at causing defoliation than girdling, but the latter was the cheapest method. The experiment is very simple and does not adequately test for sprouting because of the dense underbrush. As well, the treatments were not replicated.

Walstad, J.D. and F.N. Dost. 1984. The health risks of herbicides in forestry: a review of the scientific record. Oregon State University, Forest Research Lab, Special Publication No. 10.

Annotation: Walstad and Dost have provided a compilation of the scietific literature on health risks of herbicides. Calculations of dosages are provided for human exposure which would meet or exceed the toxicoligical points of reference established through testing of laboratory animals. They also examine data on the herbicide in the environment or organisms after use. Conclusions of medical, scientific, and herbicide data reviews are provided. They include a list of references with alternative views on the issue.